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COMBUSTION OVERVIEW

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The objective of this effort is to develop improved analytical models of the internal combustor flow field and liner heat transfer as a means to shorten combustor development time and increase turbine engine hot section life.

A four-element approach has been selected to meet this objective. First, existing models were utilized to determine their deficiencies. Supporting research was then commenced to improve the existing models. While the research effort is in progress, the models are being refined to improve numerics and numerical diffusion. And lastly, the research results and improved numerics will be integrated into existing models.

This work has been divided into seven tasks illustrated in the schedule in figure 1. One task has been completed, The Aerothermal Modeling Assessment, and one task has been suspended because of test facility closing, The Flame Radiation/Heat Flux Experiment. A new task has been added in the past year, Diffuser Studies, a jointly funded project with the Air Force. This task will be an advanced diffuser combustor analytical code.

CONTRACTOR EFFORTS

AEROTHERMAL MODELING ASSESSMENT
Aerothermal Modeling - Phase I

This work was performed under three contracts, by the following contractors and principal investigators:

Contractor	Principal investigator
Garrett Turbine Engines	R. Srinivasan
General Electric Company	M. K. Kenworthy
Pratt & Whitney Aircraft	G. J. Sturgess

A consensus of major results indicated four shortcomings in the existing models. First, faster convergence techniques via improved numerical schemes are required, as is an improved three-dimensional code coordinate system. These two are vitally necessary to reduce the size of computers required to perform the convergences. The other two shortcomings are a more accurate hot gas heat transfer input and improved turbulence and turbulence/chemistry treatment.

Status: This task has been completed. All results were published in early 1984.

COMBUSTION MODELING DEVELOPMENT
Aerothermal Modeling - Phase II

The objective of this element is to address the modeling shortcomings determined in the Aerothermal Modeling Assessment. Both analytical and experimental research will be conducted. The approaches include: incorporation of a new finite difference scheme or error reduction formula into a currently existing numerical model and experimental work to generate benchmark quality test data in the area of three-dimensional aerodynamics and combustor dynamics.

It is the intent to award five contracts under this task. These would be awarded under the following proposed titles:

Improved Numerical Methods I
Improved Numerical Methods II
Flow Interaction Experiment
Fuel Swirl Characterization I
Fuel Swirl Characterization II

Status: Contracts awarded in September 1984.

DILUTION JET ANALYSIS AND MULTIPLE JET DILUTION MIXING

The objective here is to develop correlating expressions for jet mixing in gas turbine combustors that will aid in the design of combustors and directly aid in the reduction of combustor exhaust temperature pattern factor.
A contracted study will be used to investigate the penetration and mixing of various combinations of combustor dilution jets. Effects of hole size, spacing, momentum ratio, and hole geometry are being studied, as are combustor geometric design parameters such as flow acceleration, and pressure drop is being experimentally investigated. The effects of opposed and staggered-opposed jets are being studied.

This work is being performed both under contract and as an in-house effort. The principal investigators are R. Srinivasan of Garrett Turbine Engines and J. Holdeman of NASA Lewis Research Center.

Status: Work in progress; contract effort to be completed in FY 1985.

DIFFUSER STUDIES

The objective of the Diffuser Studies is to perform analysis and diagnostic experiments necessary to develop and improve analytic models that will accurately predict the combustor-diffuser flow field for advanced aircraft turbine engines. The approach is to apply existing codes to a baseline diffuser and select the most promising. This code will be updated to handle a variety of geometric changes. The updated code will then be used to design a full annular diffuser which will be used to demonstrate and assess improved modeling capabilities.

It is a jointly funded NASA - Air Force project.

Status: Contract to be awarded in early FY 1985.

IN-HOUSE EFFORTS

FLAME RADIATION AND HEAT FLUX STUDIES

Principal Investigator, J. Wear

The objective of the Flame Radiation and Heat Flux Studies is to generate fundamental data and develop correlations needed to improve design analysis for the calculation of radiant heat transfer to combustor liner walls. This task utilized a full annular combustor designed for operation at pressures in excess of 30 atmospheres. Testing was conducted to inlet pressures of 20 atmospheres. The effects of combustor inlet conditions and fuel type were determined. Unique features included the ability to vary the primary zone fuel-air ratio while maintaining constant overall pressure loss. Both ASTM Jet A and ERBS II fuels were utilized in this program. Special instrumentation used in this program included total radiation instruments and heat flux gages, which were arranged in both axial and circumferential patterns on the outer liner.

At 15 atmospheres and 0.04 fuel-air ratio overall, 90 percent of the total heat flux was by radiation as opposed to only 40 percent at a 0.0015 fuel-air ratio. Also, total heat flux was proportional to overall fuel-air ratio in a range of pressures from 5 to 15 atmospheres.

Status: Program suspended because of test facility closing.

LINER CYCLIC TEST RIGS

The objective of the Liner Cyclic Test Rigs is to design a combustor liner low cycle thermal fatigue test facility that duplicates the actual engine creep low cycle fatigue interaction phenomena and to thermally cycle combustor liners to failure to provide data to evaluate and improve structural analysis models.

This project utilizes two test rigs, both of which operate at atmospheric pressure. One is a 5- by 8-inch flat plate cyclic rig, a totally in-house effort that serves as a test bed for special instrumentation, facility operation, and data reduction. It is shown in operation in figure 2. The principal investigators are D. Schultz from Combustion and R. Thompson from Structures. The second apparatus is a 21-inch-diameter outer liner cyclic rig shown in figure 3. This rig is being operated under a cooperative agreement with Pratt & Whitney Aircraft. Thus, in addition to Messrs. Schultz and Thompson of NASA, G. Pfeifer of Pratt & Whitney Aircraft is also a coinvestigator on this project.

Under terms of the cooperative agreement, Pratt & Whitney Aircraft supplies the test rig and NASA supplies the test facility and services. The data are shared by both.

Three flat plate cyclic rigs have been tested to date. The first rig, a three 6-kVA lamp installation, was operated under adverse conditions to determine feasibility of using quartz lamps for cyclic testing. This work, performed in December 1981, looked promising.

The second flat plate rig, again using three 6-kVA lamps, was operated to obtain instrumentation durability information and initial data input into a finite element model. This limited test program was conducted in August 1983. Five test plates were run. Instrumentation consisted of strain gages, thermocouples, and thermal paint. The strain gages failed at 1200° F, as expected, though plates were heated to 1700° F.

The third box rig, containing four 6-kVA lamps, is presently operational. In addition to 33 percent greater power input, this rig has provision for 400° F backside liner cooling air and a viewing port suitable for infrared television viewing. The casing is also water cooled for extended durability.

The 21-inch-diameter outer liner simulator uses one hundred twelve 6-kVA lamps to heat the test liner cyclicly. Power levels will be adjusted to simulate typical liner heat loadings. Air will be supplied to provide typical liner film and backside cooling. In addition to the test liners being supplied by P&W, which are production configurations, several liners will be tested to obtain confidence in the finite element model. These will consist of simple shapes, such as cylinders, and cylinders with rows of holes.

This apparatus, in addition to drawing up to 672 kVA of 480 V power, requires 7.5 lb/sec of 500° F air at 35 psia, 3.5 lb/sec of ambient temperature air at 5 psig, 1.5 lb/sec of ambient temperature air at 1 psig, and 80 gal/min of specially treated cooling water.

Special features of the latest rigs include an infrared television system for measuring backside liner temperatures without distortions caused by thermocouple lead wires, and high temperature strain gages both special 1300° F wire strain gages and laser specklegram strain systems.

Status: The bench rig is operational, while the annular rig is in startup checkout.

COMBUSTION PROGRAM SCHEDULE

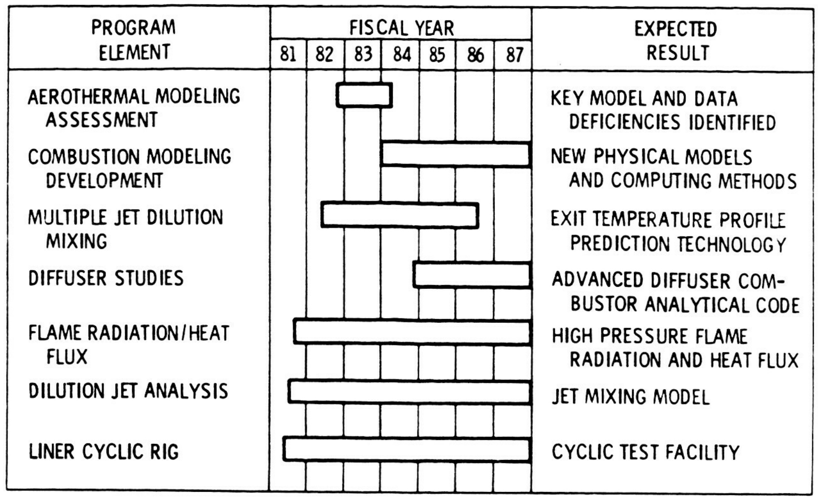

Figure 1

OPERATING CYCLIC BENCH TEST RIG

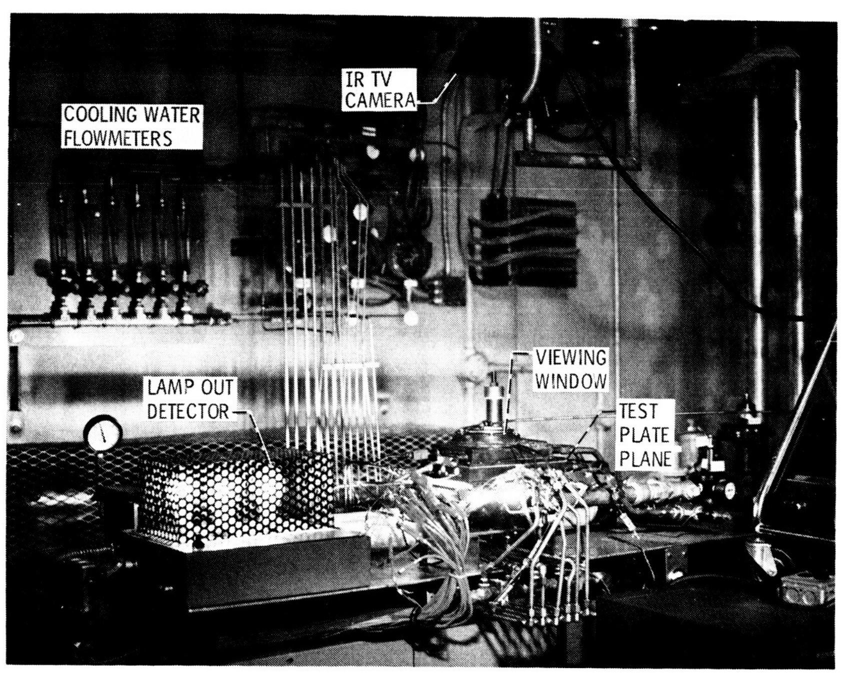

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Figure 2

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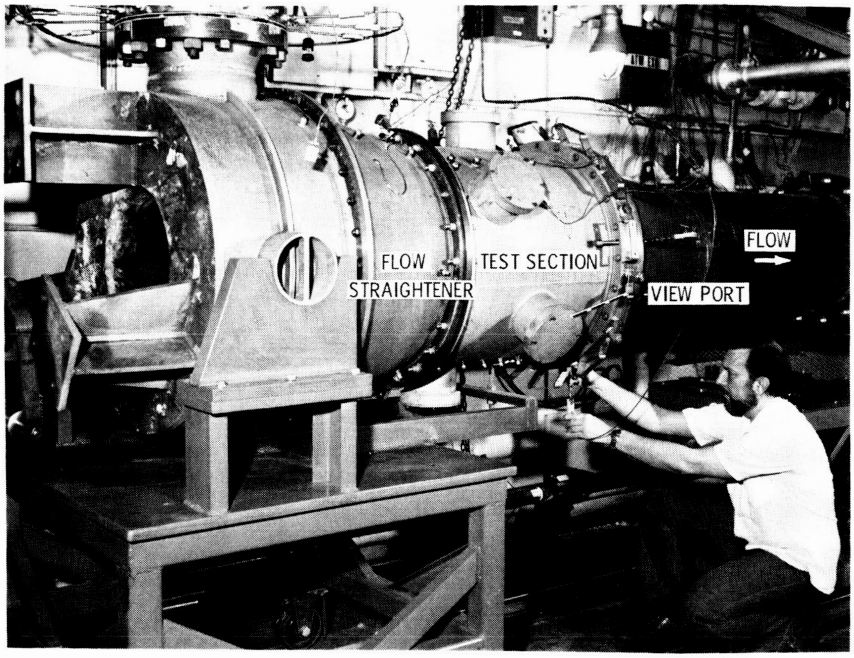
ANNULAR QUARTZ LAMP CYCLIC COMBUSTOR TEST RIG



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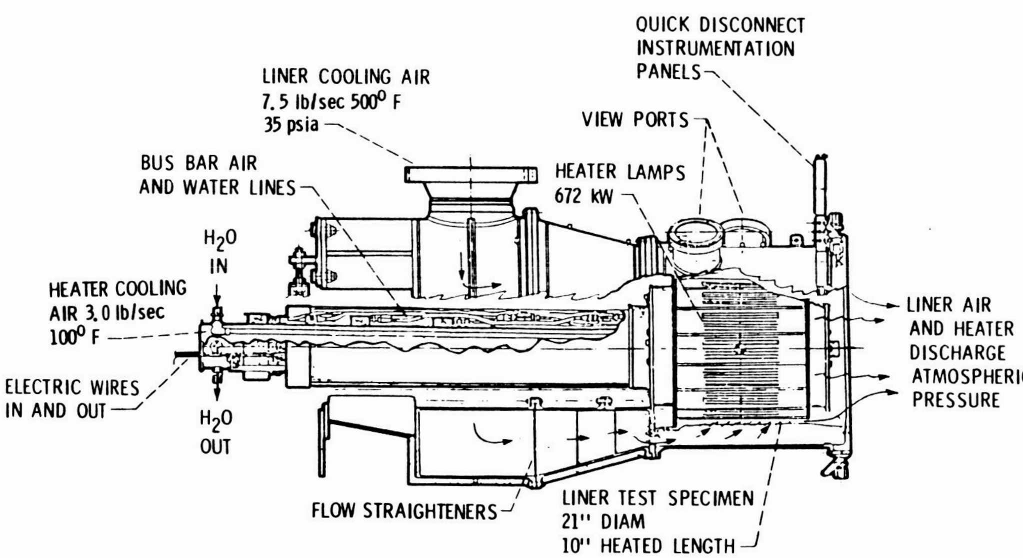

Figure 3